Evaluating Resource Management Strategies for Update 2013 of the California Water Plan

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ABSTRACT

This paper describes the analytical approach developed by the California Department of Water Resources (DWR) to evaluate the performance of alternative regional resource management strategies in meeting future water management objectives as part of the 2013 Update of the California Water Plan. The California Water Plan, mandated by state law and updated every five years, is used to guide regional and statewide water policy decisions. An overview is provided of the Plan of Study DWR developed through a rigorous public outreach process to look out to the year 2050 to define multiple plausible future scenarios that consider how future population growth, development patterns, a changing climate and other uncertainties interact to affect water management. The Water Plan has identified thirty resource management strategies that California's regions can invest in to help reduce water demand, improve operational efficiency and water transfers, increase water supply, improve flood management, improve water quality, and practice resource stewardship. The evaluation of these strategies in Update 2013 will provide decision support and guidance to California's regions and the State legislature about promising investments to improve water management in California.

INTRODUCTION

The California Water Plan, mandated by state law and updated every five years, is used to guide regional and statewide water policy decisions. DWR is working collaboratively through a rigorous public outreach process to look out to the year 2050 to define multiple plausible future scenarios that consider how future population growth, development patterns, a changing climate and other uncertainties interact to affect water management. As part of this effort, DWR has supported the development of an analytical framework that will help to evaluate the performance of alternative resource management strategies. One goal of this work is to provide guidance to California's Regions so they can carefully evaluate strategy costs, benefits, and tradeoffs in a thoughtful and collaborative way to choose cost effective and robust strategies.

UNCERTAINTIES AFFECTING FUTURE WATER MANAGEMENT

Since Update 2005 (See DWR 2005, 2009, 2010), the California Water Plan has used the concept of multiple future scenarios to capture a broad range of uncertain factors that affect water management, but over which water managers have little control. Scenarios are used to test the robustness of strategies by evaluating how well strategies perform across a wide range of possible future conditions. Robust strategies are those that perform sufficiently well in meeting water management objectives across many scenarios. The Water Plan organizes scenarios around themes of population growth, land use patterns, and climate change. Growth scenarios characterize a range of uncertainty surrounding how cities and other land managers will accommodate future population growth through infill development or expansion into areas of existing open space and agriculture. Climate scenarios explore how future climate change might influence timing, distribution, and amount of precipitation, storm runoff and water requirements.

Growth Scenarios

Future water demand is affected by a number of factors like population growth, planting decisions by farmers, and size and type of urban landscapes. Water Plan Update 2013 quantifies several factors that together provide a description of future growth and how growth could affect water demand for the urban and agricultural sectors. Growth factors are varied between the scenarios to describe some of the uncertainty faced by water managers. For example, no one can predict future population growth, so the Water Plan uses three different, but plausible population growth estimates when determining future urban water demands. In addition, the Water Plan considers up three different alternative views of future development density. Population growth and development density will reflect how large the urban landscape will become in 2050 and is used by the Water Plan to quantify encroachment into agricultural lands. Table 1 identifies the growth scenarios relative to current trends using information from the Department of Finance (DOF 2012) and

Public Policy Institute of California (PPIC 2008).

Table 1 Conceptual Growth Scenarios

Scenario	Population Growth	Development Density
1	Lower than Current Trends	Higher than Current Trends
2	Lower than Current Trend	Current Trends
3	Lower than Current Trends	Lower than Current Trends
4	Current Trends	Higher than Current Trends
5	Current Trends	Current Trends
6	Current Trends	Lower than Current Trends
7	Higher than Current Trends	Higher than Current Trends
8	Higher than Current Trends	Current Trends
9	Higher than Current Trends	Lower than Current Trends

Source: California Department of Water Resources 2012 (unpublished).

Table 2 Growth Scenarios (urban) – Statewide values (DRAFT)

2006 Population was 36.1 million

2006 Urban Footprint was 5.25 million acres

Scenario	2050 Population (millions)	Population Change (millions) 2006 to 2050	Development Density	2050 Urban Footprint (million acres)	Urban Footprint Increase (million acres) 2006 to 2050
1	43.9[a]	7.8	High	5.99	0.74
2	43.9	7.8	Current Trends	6.10	0.85
3	43.9	7.8	Low	6.21	0.96
4	51.0[b]	14.9	High	6.65	1.40
5	51.0	14.9	Current Trends	6.81	1.56
6	51.0	14.9	Low	6.98	1.73
7	69.4[c]	33.3	High	7.55	2.30
8	69.4	33.3	Current Trends	7.86	2.61
9	69.4	33.3	Low	8.17	2.92

Source: California Department of Water Resources 2012 (unpublished).

a Values modified by Department of Water Resources from the Public Policy Institute of California (PPIC 2008)

b Values from Department of Finance (DOF 2012)

c Values modified by Department of Water Resources from the Public Policy

Institute of California (PPIC 2008)

For Update 2013, DWR worked with researchers at the University of California, Davis to quantify how California might grow through 2050. The UPlan model (Johnston et al, 2003) was used to estimate a year 2050 urban footprint under the scenarios of alternative population growth and development density listed in Table 2. UPlan applies Geographic Information System technology with rules describing where future growth might occur to quantify the land area devoted to urban uses. Locations for future growth follow local General Plan rules as well as attractors to growth like roads and distracters to growth like land use restrictions. Table 2 describes the amount of land devoted to urban use for 2006 and 2050 and the change in the urban footprint for California under each scenario. Table 3 describes how future urban growth could impact the land devoted to agriculture in 2050. Irrigated land area is the total agricultural footprint. Irrigated crop area is the cumulative area of agriculture considering that many parts of the state plant and harvest more than one crop per year, known as multi-crop area. Each of the scenarios shows a decline in irrigated acreage over existing conditions, but to varying degrees.

Table 3 Growth Scenarios (agriculture) - Statewide values (DRAFT)

2006 Irrigated land area was estimated by DWR to be 8.68 million acres

2006 Irrigated crop area was estimated by DWR to be 9.33 million acres

2006 Multiple crop area was estimated by DWR to be 0.65 million acres

Scenario	2050 Irrigated Land Area (million acres)	2050 Irrigated Crop Area (million acres)	2050 Multiple Crop Area (million acres)	Reduction in Irrigated Crop Area (million acres) 2006 to 2050
1	8.42	9.06	0.64	0.27
2	8.38	9.02	0.64	0.31
3	8.35	8.98	0.63	0.35
4	8.24	8.86	0.62	0.47
5	8.18	8.80	0.62	0.53
6	8.13	8.74	0.61	0.59
7	8.01	8.61	0.60	0.72
8	7.92	8.50	0.58	0.83
9	7.82	8.40	0.58	0.93

Source: California Department of Water Resources 2012 (unpublished).

Climate Scenarios

Update 2013 is taking a quantitative look at the uncertainty surrounding future climate change when evaluating the performance of new resource management strategies. After consultation with its Climate Change Technical Advisory Group, DWR chose to include as many as 18 alternative climate scenarios in the evaluation of future strategies. These include 12 climate scenarios identified by the Governor's Climate Action Team (CAT 2009), 5 climate scenarios developed by the Bureau of Reclamation for the Central Valley Project Integrated Resource Plan (USBR 2012, under development), and a scenario representing a repeat of historical climate. Each of the climate scenarios has separate estimates of future precipitation and temperature. Collectively these estimates provide planners with a range of precipitation and temperature that might be experienced in the future and are used with other factors to estimate future water demands.

Figure 1 shows the variation in 30 year running average annual precipitation for Red Bluff located in the Central Valley for the 1915-2003 historical period and U.S. Bureau of Reclamation scenarios of future climate, and 2011-2099 for the 12 CAT scenarios of future climate. The variation in the 30 year running average precipitation is represented as a box plot (also known as a box-and-whisker diagram or plot), which is a convenient way of graphically summarizing groups of numerical data using five numbers (the smallest observation, lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation). For example, for the historical period, the box plot shows a minimum value of about 20 inches in the driest 30 year period and a maximum value of slightly over 23 inches in the wettest 30 year period.

Figure 2 shows the trend in the change in average annual temperature for the Sacramento Valley floor for each climate sequence compared against the 1951–2005 historical average. A distinct upward trend in temperature change is shown in each climate scenario. However, there is considerable year-to-year fluctuation and different expectations for the long-term magnitude in temperature change. While the absolute change in temperature varies from region to region, the relative change in average annual temperature follows a similar pattern in all regions to that shown for the Sacramento River Hydrologic Region in Figure 2.

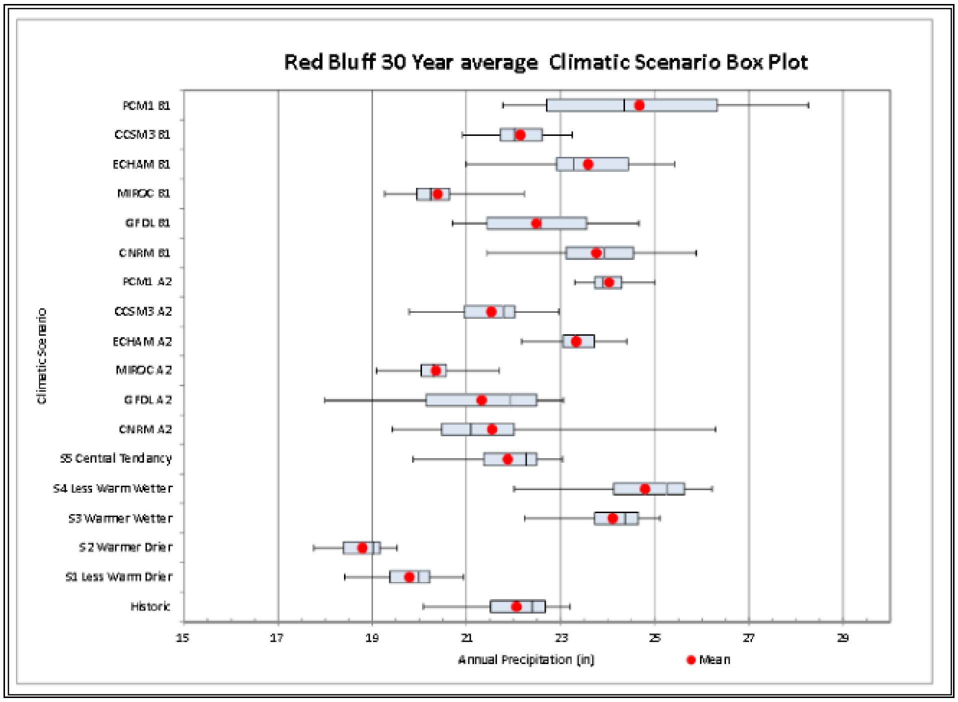

Figure 1 Variation in 30 Year Running Average Precipitation for Red Bluff for Historical Record (1915-2003) and Alternative Scenarios of Future Simulated Climate (2011-2099)

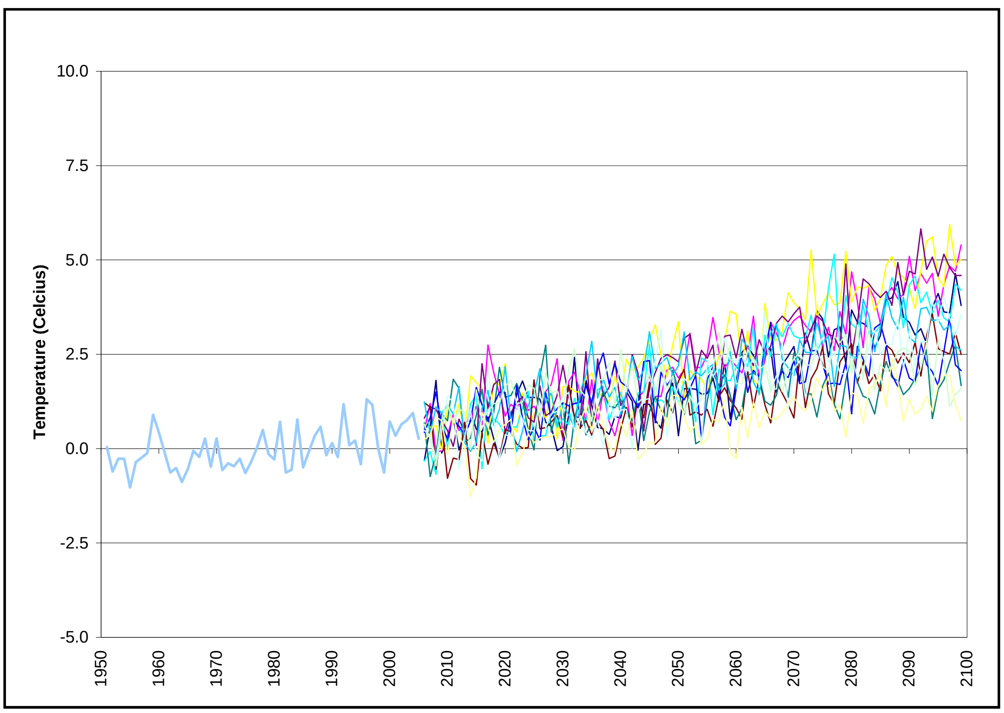

Figure 2 Change in Average Annual Temperature for Sacramento Valley Floor from Historical 1951-2005 Average for Historical Period and 12 Scenarios of Future Climate Years 2006-2100

Future Environmental Requirements

The Water Plan uses currently unmet environmental objectives as a surrogate to estimate new requirements that may be enacted in the future to protect the environment or new ecosystem restoration actions implemented for example, under an integrated regional water management plan. These unmet objectives are instream flow needs or additional deliveries to managed wetlands that have been identified by regulatory agencies or pending court decisions, but are not yet required by law. For Update 2013 the Water Plan has identified the following unmet objectives.

- American (Nimbus) Department of Fish and Game Values
- Stanislaus (Goodwin)
- Ecosystem Restoration Program #1, Delta Flow Objective
- Ecosystem Restoration Program #2, Delta Flow Objective
- Ecosystem Restoration Program #4, Freeport
- Trinity below Lewiston
- Ecosystem Restoration Program #3 San Joaquin River at Vernalis
- San Joaquin River below Friant
- Level 4 Water Deliveries to Wildlife Refuges

These are only some of the unmet objectives and do not include all new anticipated environmental objectives in the state. In particular, they do not include additional water to protect species in the Delta resulting from the December 2008 Delta Smelt Biological Opinion issued by the U.S. Fish and Wildlife Service or to protect salmon and several other species resulting from the June 2009 biological opinion by the National Marine Fisheries Service.

EVALUATING RESOURCE MANAGEMENT STRATEGIES FOR THREE HYDROLOGIC REGIONS

Throughout development of Update 2013 DWR has worked with the Statewide Water Analysis Network (SWAN serves as the technical advisory committee for the Water Plan) to develop methods to regionally quantify and evaluate the costs, benefits, and tradeoffs of different resource management strategies through the application of the Water Evaluation And Planning (WEAP) modeling platform. The Water Plan is testing the evaluation methods by focusing on the three hydrologic regions capturing the Central Valley: The Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions (see Figure 3). The proposed analysis for these three regions has been documented in the Plan of Study for Update 2013 (DWR 2012).

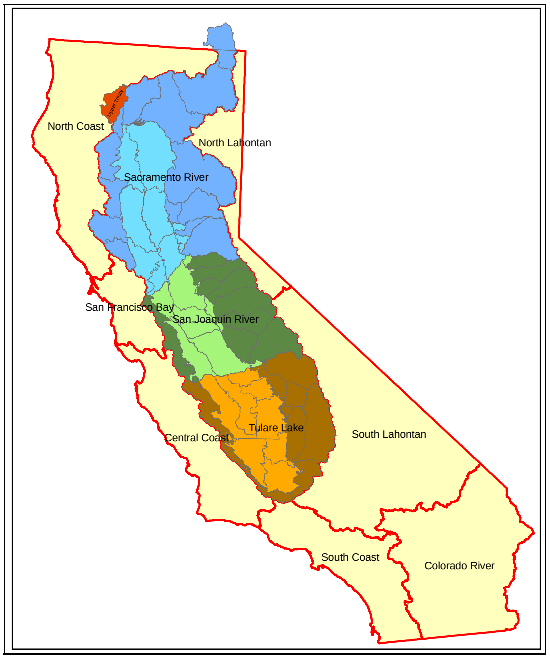

Figure 3 California's Hydrologic Regions Highlighting Three Central Valley Regions Used in Test Case

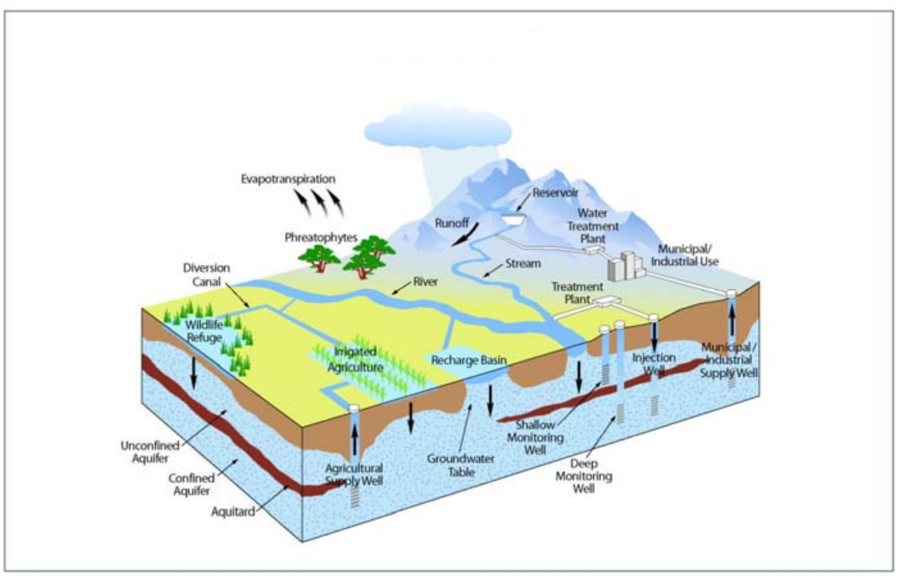

Figure 4 Conceptual Model of Water Management System

Table 4 summarizes the Update 2013 Plan of Study components in terms of the key uncertain scenario factors, performance metrics, resource management strategies and response packages, and relationships. This table, also called an XLRM matrix (Lempert et al., 2003), summarizes these elements and is designed to clearly distinguish among the uncertain factors (X) that are used to develop the uncertain scenarios; the water management strategies or levers (L) that comprise the response packages; the performance metrics (M) that are used to evaluate and compare response packages; and the relationships (R) among these elements that are reflected in the planning models. DWR used this matrix when developing the scoping of the analysis and communicating it to stakeholders. See the Plan of Study for a detailed description of each factor shown in Table 4.

WEAP is used to represent both the physical water management system and existing and potential resource management strategies. The physical water management system is represented by estimates of current and future precipitation, runoff to streams and rivers, flows into surface reservoirs, and many other components represented conceptually in Figure 4.

Table 4 Update 2013 Plan of Study Components (DRAFT)

Uncertain factors (X)	**Resource management strategies (L)**
• Demographics • Urban and agricultural footprint • Climate conditions • Costs of resource management strategies	• Urban and agricultural water use efficiency • Recycled municipal water • Conjunctive management and groundwater storage • Surface storage • New instream flow objectives • Groundwater overdraft recovery
Relationships (R)	**Performance metrics (M)**
• Water Evaluation And Planning system (WEAP) Central Valley Model • UPlan urban growth model • Statewide Agricultural Production model (SWAP) • Demographic analysis • Costs and economic impact tools	• Urban supply reliability • Agricultural supply reliability • Instream flow reliability • Groundwater levels • Sacramento-San Joaquin River Delta exports (Central Valley Project and State Water Project) • Cost of implementing response packages • Economic impacts of unmet water demand

Source: California Department of Water Resources 2012.

Management Response Packages

As described in the Plan of Study, Update 2013 evaluates several management response packages, each comprised of a mix of resource management strategies that are implemented at specific levels and locations. The focus of this analysis will be for the Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions, and will include strategies that are regionally significant. For example, a response package could include improvements in urban water use efficiency that is specified to increase to 20 percent savings by 2020, additional groundwater storage, or increasing water for ecosystem restoration.

These response packages will not represent a definitive set of alternatives; rather illustrate different levels of strategy diversification that could be taken to address water management challenges. Each response package emphasizes one or more of the strategy categories. Table 5 lists a preliminary proposal for the relative levels of strategy emphasis by category for seven response packages. The corresponding implementation rules for each strategy are under development. Additional response packages may be developed that are specifically tailored to address the vulnerabilities of currently planned management.

Table 5 Resource Management Strategies Used in Plan of Study (DRAFT)

Response Package	Resource Management Strategy Category					
	Environmental flow recovery targets	**Ground-water recovery targets**	**Water use efficiency**	**Recycled municip al water**	**Conjun ctive manage ment**	**Surface storage**
Currently planned	Current	Current	Currently planned	Current	Current	Current
Diversification Level 1	Medium	Medium	High	Medium	Current	Current
Diversification Level 2	Medium	Medium	High	High	Medium	Current
Diversification Level 3	Medium	Medium	High	High	High	Current
Diversification Level 4	High	High	High	High	High	New North of Delta
Diversification Level 5	High	High	High	High	High	New South of Delta
Diversification Level 6	High	High	High	High	High	New North of Delta + South of Delta

Work-in-Progress

At the time of writing this paper the authors were conducting initial analysis of the *currently planned* response package described in Table 5 for the Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions (See Figure 3). These results will provide the basis for a vulnerability analysis for water conditions through the year 2050 without significant investment in new strategies. During the first quarter of 2013 the Water Plan will be present these initial results through stakeholder meetings while work continues to complete the analysis of all response packages shown in Table 5 for the Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions. When completed, the analysis will evaluate the performance of all strategies shown in Table 5 with respect to the performance metrics shown in Table 4.

Limitations of Future Water Management Analysis for Update 2013

The analysis of resource management strategies developed for Update 2013 can allow comprehensive analysis of strategy performance when conducted at sufficient detail. However, all technical endeavors are subject to the limits of the particular technology being used and the financial resources available. Below are some of the important limitations identified for the analysis used for Update 2013.

- For Update 2013, DWR is testing the more comprehensive analysis described in this paper for the Sacramento River, San Joaquin River, and Tulare Lake Hydrologic Regions. The analysis for the remaining 7 hydrologic regions in California will be coarser and focus on quantifying future water demands under alternative future scenarios similar to the analysis performed for Update 2009.
- Many of the resource management strategies identified in the Water Plan can be represented in the Update 2013 application of WEAP, particularly those related to the water management objectives to reduce water demand, improve operational efficiency and transfers, and increase water supply. However, the analysis for Update 2013 will have limited or no ability to quantify strategies that improve flood management, improve water quality, and practice resource stewardship. These will be considered as part of future enhancements to the analytical framework.
- The analysis for Update 2013 will quantify some of the resource management strategy benefits for providing a supply benefit, improving drought preparedness, environmental benefits, operational flexibility and efficiency, and reducing groundwater overdraft. There is limited or no ability to quantify benefits for improving water quality, reducing flood impacts, energy benefits, and recreational opportunities; however, these may be described qualitatively. Quantifying these other benefits will be considered as part of future enhancements to the analytical framework.
- The conceptual water management system in Figure 4 captures many of the hydrologic and water management components that are represented in the

analytical framework for Update 2013. The analysis to support the Water Plan is designed to represent the water management system at sufficient detail to reflect important regional planning conditions, but not for detailed water project operations or to capture all detailed flows through the system. As a result, many system features, such as groundwater basins, are simplified to capture the broad regional behavior of groundwater recharge, groundwater storage, and hydrologic connection to rivers and lakes. Significant refinement in the analysis will be needed to support decisions by individual water districts.

CONCLUSION

This paper describes the analytical methods employed by the California Department of Water Resources for Update 2013 of the California Water Plan to evaluate how statewide and regional water demands might change by 2050 in response to uncertainties surrounding future population growth, land use changes, the effect future climate change, and other factors. These future uncertainties will play out quite differently across the regions of California, so each region will need to choose and implement a portfolio of resource management strategies that satisfy regional water management goals and objectives. The paper describes methods for a more comprehensive vulnerability analysis for the Sacramento River, San Joaquin River, and Tulare Lake regions to test longer term analytical enhancements for the Water Plan. This analysis is testing different response packages, or combinations of resource management strategies, under many future uncertainties. These response packages help decision-makers, water managers, and planners develop and evaluate integrated water management plans that invest in actions with more sustainable outcomes. Final results of this analysis will be presented in the final Update 2013 of the Water Plan due to be published early in 2014.

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